GUIDE

FOR USING DAVIS' NEW

Geographical and Astronomical

APPARATUS.

ASTRONOMY

GEOGRAPHY

DAVIS & WOODS,

129 SMITHFIELD STREET, PITTSBURGH, PA.

AGENTS.

NOTWITHSTANDING a very brief period has elapsed since the LUNATELLUS and HELIOTELLUS were brought before the public, and but little effort made to sell them, they are, through their own *intrinsic merit,* finding their way into the best Academies, Seminaries and Public Schools of our Country. The Public Schools of Boston, Philadelphia, Pittsburgh, Allegheny, and those of many other Cities and Towns, East and West, are using them with much profit in their *Primary,* as well as in their Advanced Classes; also, many of the best High Schools, Academies, Seminaries and Colleges have adopted them as a *permanent* and *almost indispensable* piece of School Apparatus. All Teachers and Educators, and every person interested in Education are *especially invited* to examine *with care the accuracy* of these Instruments, and their adaptation for Educational Purposes.

Lunatellus or Heliotellus

SHOULD BE IN EVERY SCHOOL AND FAMILY.

1. On account of their accuracy in giving just conceptions of the fundamental principles of Science.

2. On account of their accuracy in illustrating the grand mechanism of the Solar System.

3. On account of their accuracy in illustrating the mutual relations of Geography and Astronomy.

4. On account of the natural causes and great variety of natural phenomena which they illustrate.

5. On account of their illustrating phenomena which cannot be learned from Maps and Charts.

6. On account of their illustrating many natural causes and phenomena which *all other Apparatus fails* to illustrate.

7. On account of the ease with which knowledge is imparted by their use.

8. On account of the ease with which knowledge is acquired by their use.

9. On account of the lasting impressions which their movements make upon the mind.

10. On account of their practical adaptation to the Library School-room and purposes for which they are designed.

11. On account of the vast amount of labor and time they save both Teacher and Pupil.

12. On account of the satisfaction enjoyed by both Teacher and Pupil in imparting and receiving instruction.
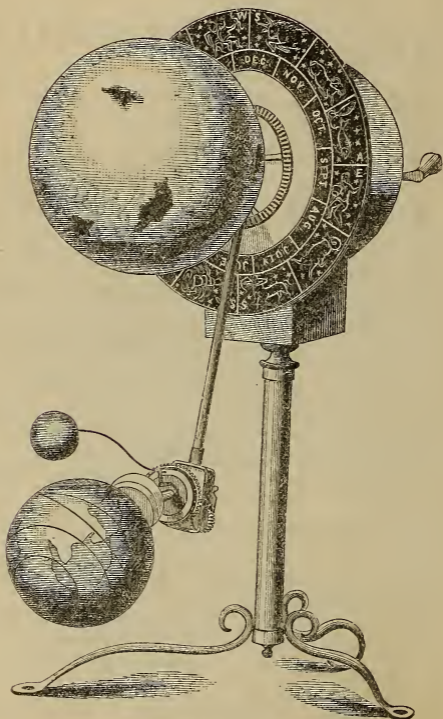
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Fig. 3.—Large Lunatellus.

LUNATELLUS AND HELIOTELLUS.

These Instruments, on account of their *novelty of form and accuracy of movement*, were recently patented in the United States, Russia, France, England, and other countries of Europe. The Lunatellus is the Tellurian in a *new form*, and *so improved* as to illustrate the Astronomical phenomena of the Sun, Earth and Moon in their natural order, with the Geography of the Earth always in its proper relation to them. The Heliotellus. *See next Cut.*

SUN.

The Sun is represented by a globe eight inches in diameter, and is attached by one of the poles to a rod that connects with the gearing.

EARTH.

The Earth is represented by a globe five inches in diameter—is pivoted by the North Pole to the gearing, and is covered with a Geographical Map. This globe can be detached in a moment, from the gearing and placed on a stand for separate use.

MOON.

The Moon is represented by a smaller globe relative in size to that of the Earth, and is carried by a wire which passes through its poles and is attached to the gearing.

GEARING.

The Lunatellus is operated entirely by metallic gearing, part of which is inside the case and part at the outer end of the arm that carries the Earth and Moon. The large wheel at the outer end of the arm that carries the Earth, to which is attached a disk slightly inclined, causes the Moon to move in an elliptical orbit, and also to cross the plane of the Ecliptic north and south at an angle of about 5 degrees; also, her nodes to retrograde a degree and a fraction every lunation, thereby causing the Moon to complete her cycle in proper time, while the earth is making eighteen revolutions and a fraction around the Sun.

ZODIAC.

A Zodiac thirty inches in circumference containing the *twelve signs*, and the months in the year corresponding with them is permanently attached to the case.

MOTION.

The Lunatellus is put in motion by means of a crank which connects in the back part of the case with the gearing.

CONVENIENCE.

This Instrument is always ready for use; weighs only a few pounds; occupies but little space, and is put in motion with a few ounces of pressure on the crank.

DURABILITY.

With proper care this Instrument will last a lifetime, as it is composed wholly of metal, except the Maps, and every part free from strain or undue pressure.

UTILITY.

Geography is so plainly illustrated, and the varied phenomena of the Sun, Earth and Moon are *expressed* with such *precision* and *accuracy* by the Lunatellus, that more can be learned, even by youth, in a few lessons, than can be learned in months without it, hence its necessity in every Family and School.

INDICATOR.

The Indicator is seperate from the Instrument, and circular in form, with a hole in the centre sufficiently large to admit the globe that represents the Earth.

DUPLICATE.

An *exact duplicate* of any part of the Lunatellus or Heliotellus can be obtained by applying to any of the Agents, Proprietors or Patentee.

Geography and Astronomical Phenomena

Illustrated by Davis' Apparatus.

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EXPLANATIONS AND REMARKS.

I. The terms *down* and *up* are merely *relative*, meaning towards or from the centre of the Earth. If two persons are on opposite sides of the Earth, the direction which is down to one is up to the other.

The terms *top, under, above, below,* &c., when applied, in illustrating, to the globular bodies of the Apparatus, have the same meaning that we attach to them when applied to other bodies around us.

II. The terms *East* and *West* are relative, for by pointing eastward for twenty-four hours we point to every star on the same parallel, since the earth makes one revolution on her axis in twenty-four hours.

The *East* and *West points* are where the sun rises and sets when the earth is at either Equinox.

III. The Natural Zodiac is an imaginary belt 16° in width, extending around the heavens east and west. It is divided into twelve equal parts called *signs*. Each sign contains a conspicuous group of stars, and these groups are called *constellations*. Each *constellation* was named early in the history of Astronomy, and each sign received the same name that the constellation had at that time. The plane of the Ecliptic divides the Zodiac into two equal parts, 8° being on each side north and south.

IV. The signs and constellations of the same name in the Natural Zodiac, coincided about 2,200 years ago. Since that time the first point of the *sign* Aries (the Ram) has moved westward about 31° with the Equinox, with which it has always coincided. Now the first point of the *sign* Aries, and the first point of the *constellation* Pisces (the Fishes), pretty nearly coincide, and the first points of the sign Taurus (the Bull) and constellation Aries, &c.

V. The Equinoctial and Solsticial points, as marked on the Zodiac of the Lunatellus and Heliotellus, are not named as they are generally, from the apparent position of the sun in the Ecliptic at different seasons of the year, but from the position of the Earth in her orbit at different periods. For the sake of convenience, the Zodiac of the Instruments is made small and attached to the front part of the case.

VI. To give the Lunatellus a favorable position, place the back towards the north, and for latitude 40° north, if it is desired to have the planes of the earth's Equator and Ecliptic in the Instrument parallel with those in nature, lean the top of the Instrument forward about $16\frac{1}{2}$°.

VII. It will not injure the Instrument to turn the crank in either direction, but by turning it from *left* to *right* the Sun, Earth and Moon will have their natural direction through the signs of the Zodiac.

VIII. The *Sun* in the heavens always *enlightens the half of each body* in the solar system *next himself;* consequently, *that half of the Earth and Moon next himself is always enlightened.* In illustrating with this Instrument we will regard the Sun AS LUMINOUS, and always shedding his rays on *that half of the earth and moon next himself.* Where the light of day and darkness meet around each of these bodies, is called the CIRCLE OF ILLUMINATION.

IX. In the following illustrations the *globular bodies* of the Apparatus receive the natural names of Sun, Mercury, Venus, Earth, and Moon, and it is presumed that the *learner is situated on the body that represents the Earth,* which is called Earth.

𝕲eography and 𝕬stronomical 𝕻henomena

ILLUSTRATED BY THE

LUNATELLUS.

ILLUSTRATION 1.

MOTIONS OF THE SUN, EARTH, AND MOON, AND DIRECTION OF THEIR MOTIONS.

By connecting the crank with the gearing, and turning it the proper direction, from *left to right*, motion is imparted to the Sun, earth and moon. The direction of the Sun's motion on his axis; the Earth's annual motion around the Sun, and her daily motion on her axis; and the motions of the Moon around the Sun, around the Earth, and also on her axis, are in the same general direction, *Eastward*.

ILLUSTRATION 2.

THE PLANE OF THE ECLIPTIC, AND ITS RELATION TO THE PLANE OF THE EQUATOR.

Place the Indicator around the Earth, with one part touching the Tropic of Cancer, on *top* of the Earth, and another touching the Tropic of Capricorn, *under* the Earth, crossing the Equator on the *east* and *west* sides of the Earth, at an angle of about $23\frac{1}{2}°$, and it will represent the plane of the Ecliptic in its proper relation to the plane of the Equator.

ILLUSTRATION 3.

INCLINATION OF THE EARTH'S AXIS, AND ITS PARALLELISM.

Place the Indicator on the Earth so that it will represent the plane of the Ecliptic, and it may be readily perceived that the

Earth's axis is *leaned* about $23\frac{1}{2}°$ from an imaginary line passing through the centre of the Earth, perpendicular to the plane of the Ecliptic. Revolve the Earth once around the Sun, and the imaginary lines that represent the position of the Earth's axis at every point in her orbit *are parallel* to each other.

ILLUSTRATION 4.

CAUSE OF DAY AND NIGHT.

The Earth being globular and opaque, the Sun always enlightens *that half next himself*, making *day*, while the other half which is opposite to him is in darkness, making *night*. By giving the Instrument motion, the Earth turns on its axis, and *that half* which is in the *Sun light* is turned into the shade of the Earth, which is *night*, while the *other half* which is in darkness, is turned into *Sun light*, which is *day*.

ILLUSTRATION 5.

DAY AND NIGHT EQUAL, AND CAUSE.

Give the Instrument motion till the Earth arrives at *V. E.*, as marked on the Zodiac, indicating Vernal Equinox, or at *A. E.*, indicating Autumnal Equinox, and it is apparent that each pole is equally distant from the Sun, and that the *light* of the Sun *extends to each pole;* consequently half of the Equator is in the presence of the Sun, and half in darkness, and if the Earth is made to turn uniformly on her axis, as in nature, *each half* will pass through the *same space* in the *same period*, hence the equality of day and night.

ILLUSTRATION 6.

LONG DAYS AND SHORT NIGHTS IN THE NORTHERN HEMISPHERE.

Give motion to the Instrument till the Earth arrives at the point in the Zodiac marked *S. S.*, indicating Summer Solstice. Apply the Indicator around the Earth to the *circle of illumination*, which is *below* the north pole $23\frac{1}{2}°$, and *above* the south pole the same number of degrees, and more than half of the Northern and less than half of the Southern Hemisphere is enlightened. Give the Earth, by turning the crank, a uniform motion on her axis, as in

nature, and the *cause* of the long days and short nights in the northern hemisphere, and short days and long nights in the southern hemisphere is apparent.

ILLUSTRATION 7.

LONG DAYS AND SHORT NIGHTS IN THE SOUTHERN HEMISPHERE.

Give motion to the Instrument till the Earth arrives at that point of the Zodiac marked W. S. indicating Winter Solstice. Apply the Indicator around the Earth on the *circle of illumination*, which is *below* the north pole 23½ degrees and *above* the south pole the same number of degrees, and more than half of the southern and less than half the northern hemisphere is enlightened. Give the Earth, by turning the crank, a uniform motion on her axis, as in nature, and the *cause* of the short days and long nights in the northern hemisphere, and the long days and short nights in the southern hemisphere is apparent.

ILLUSTRATION 8.

SIX MONTHS DAY AT THE NORTH POLE, AND SIX MONTHS NIGHT AT THE SOUTH POLE, AND VICE VERSA.

Bring the Earth to the Vernal Equinox and each pole will be equally distant from the Sun, and his light will extend to each pole. Turn the crank and apply the Indicator on the *circle of illumination* around the Earth, at any point in her orbit whilst she is making half of a revolution around the Sun, (equal half a year,) and it will pass outside the north pole from the Sun and inside of the south pole. The Sun being constantly above the Indicator the north pole will enjoy his light, while the Earth is making half a revolution around the Sun, (equal to six months,) and the south pole will be in darkness the same number of months. (When the earth is at the Summer Solstice the light of the Sun will extend below the north pole 23½ degrees, and be withdrawn from the south pole the same number of degrees.) Continue the motion of the Earth in her orbit till she passes from the Autumnal to the Vernal Equinox, (equal half a year,) and consider the *constant change of the circle of illumination*, and it will be apparent

that there will be *day* during all this time at the south pole and *night* at the north pole. (When the Earth is at the Winter Solstice the light of the Sun extends above the south pole 23½ degrees and is withdrawn from the north pole the same number of degrees.)

ILLUSTRATION 9.

CAUSE OF THE INEQUALITY IN LENGTH OF DAYS AND NIGHTS.

Were the Earth's axis perpendicular to the plane of the Ecliptic, the planes of the Equator and Ecliptic would coincide, and day and night would be always equal, as the light of the Sun would constantly extend to each pole, but the *inclination and parallelism of the Earth's axis and her annual motion*, as may be observed by giving the earth a complete revolution around the sun, *cause* more than half the northern hemisphere to be enlightened each alternate half year, and more than half of the southern hemisphere to be enlightened each alternate half year, hence the inequality in the length of days and nights in each hemisphere.

ILLUSTRATION 10.

CHANGE OF SEASONS, AND CAUSE.

As a rule the *more direct* the Sun's rays are on any portion of the earth, the warmer it is. Bring the earth to the Summer Solstice and the rays of the Sun will be *direct* on the Northern Tropic. Revolve her slowly to the Winter Solstice and the Sun's rays *will be direct on every parallel* between the Tropics. Continue her in her orbit to the Summer Solstice and his rays will again be direct on every parallel between the tropics, hence the change of seasons. This change of place of the Sun's direct rays *is caused* by the *inclination* and *parallelism* of the *earth's axis* and *her motion around the sun*.

ILLUSTRATION 11.

CAUSE OF THE ZONES, AND THEIR WIDTH.

Bring the Earth to the Summer Solstice and the Sun will be north of the Equator 23½ degrees. Revolve her to the Winter Solstice and he will be 23½ degrees south of the Equator. This change of

the Sun from his extreme point north to his extreme point south is produced by the *inclination of the Earth's axis* and *her annual revolution around the Sun.* Double 23½ degrees, the amount of the inclination of the Earth's axis, and *the sum* will represent the *width* of the torrid zone. The distance of the polar circles from the poles is equal to 23½ degrees which equals the inclination of the Earth's axis. The temperate zones are limited by the tropics and polar circles.

ILLUSTRATION 12.

WINTER IN THE NORTHERN HEMISPHERE WHEN THE EARTH IS NEAREST, AND SUMMER WHEN THE EARTH IS FARTHEST FROM THE SUN.

Bring the Earth to the Winter Solstice, as marked on the Zodiac, where she is nearest to the Sun, and *his rays* will be *oblique* to the northern hemisphere, hence winter there. Next bring the Earth to the Summer Solstice where she is farthest from the Sun, and his rays will be *direct* on the northern tropic, hence summer in the northern hemisphere.

ILLUSTRATION 13.

THE SUN RISING NORTH OF THE EAST POINT, AND SETTING NORTH OF THE WEST POINT, AND RISING SOUTH OF THE EAST POINT, AND SETTING SOUTH OF THE WEST POINT.

Revolve the Earth around the Sun and it will be apparent that in consequence of the inclination of her axis, and her annual motion, that the Sun will be, during each alternate half year, *north* and *south* of the Equator. While he is north of the Equator he will *rise north* of the east *Point*, and *set north* of the west *Point*, and while he is south of the equator he will *rise south* of the east *Point*, and *set south* of the west *Point*.

ILLUSTRATION 14.

CAUSE OF THE SUN RISING EARLIER TO PLACES EAST OF US.

It will be remembered that East is a relative term, and in general, indicates the direction of the Sun's rising. To simplify this illustration bring the Earth to the Vernal Equinox, and apply the

Indicator around the Earth *on the circle of illumination* which passe through the poles and divides the Equator into *two equal parts.* Revolve the Earth, and as she turns *Eastward* on her axis, those portions of her near the *eastern line of illumination* will be brought into the presence of the sun sooner than those parts further west.

ILLUSTRATION 15.

CAUSE OF THE APPARENT MOTION OF THE SUN, MOON AND STARS, FROM EAST TO WEST.

By giving motion to the Instrument, the Earth may be seen turning *Eastward* on its axis, which causes the apparent westward motion of the Sun, Moon and Stars.

ILLUSTRATION 16.

DECLINATION OF THE SUN, OR HIS APPARENT MOTION NORTH AND SOUTH.

Bring the Earth to the Winter Solstice, and the Sun's rays will be direct on the southern tropic, and as she is being revolved to the Summer Solstice, he will seem to move north till his rays are direct on the northern tropic. Continue the Earth's annual motion till she arrives again at the Winter Solstice, and the Sun will appear to move south. This apparent motion of the Sun North and South is called *declination,* and is caused by the *inclination* of the *Earth's axis, its parallelism,* and *her annual motion.* The Sun's declination is measured from the Equinoctial North and South.

ILLUSTRATION 17.

RELATIVE POSITION OF THE EARTH TO THE SUN AT ANY GIVEN PERIOD OF THE YEAR.

Revolve the Earth around the Sun, and when the arm that carries the Earth is *over each space of the Zodiac* that represents each month of the year, she will sustain her proper position and relation to the Sun, at every point in her orbit.

ILLUSTRATION 18.

THE SUN AND EARTH ALWAYS IN OPPOSITE SIGNS OF THE ZODIAC.

The natural position of the Zodiac is outside of the orbit of the Earth, and the plane of the Ecliptic divides it into two equal parts, 8° being on each side, North and South. As the Earth enters one sign, the Sun enters the sign opposite, as may be seen by observing how the Sun and Earth are related to the Zodiac when motion is given to the Instrument. When the *Earth is at the Vernal Equinox*, by looking towards the Sun, along the arm that carries the Earth, he will appear at the *Autumnal Equinox*, and when the Earth is at the Summer Solstice, he will appear at the Winter Solstice, &c.

ILLUSTRATION 19.

ELLIPTICITY OF THE EARTH'S ORBIT.

It may be observed by giving the Earth one complete revolution around the Sun, and measuring her distance from the Sun at the Solstices and Equinoxes, that the *Earth gradually leaves the Sun* in her passage from the Winter to the Summer Solstice, and that she gradually *advances nearer* to the Sun as she passes from the Summer to the Winter Solstice, hence the *curve* that she describes is an *ellipse*, and the Sun is in one of the foci.

ILLUSTRATION 20.

INEQUALITY OF SIDERIAL AND SOLAR DAYS, AND CAUSE—366 REVOLUTIONS OF THE EARTH ON HER AXIS NECESSARY TO PRODUCE 365 DAYS.

The length of the Siderial Day is the time that it requires the Earth to rotate once on her axis, and the length of the solar day is the time that elapses between two consecutive transits of the Sun over any given meridian. To make this illustration plain, bring the Earth to the Summer Solstice, and bring any meridian directly *under* the Sun, and it will pass over the *top* of the Earth. If motion is given to the Instrument till the same meridian is brought round on *top* of the Earth again, this rotation of the Earth represents a Siderial Day; but the solar day is not complete till the same me-

ridian is brought again *directly between* the Sun and Earth, conse-
quently the solar day is 1-365th longer than the siderial day,
which is caused by the *annual*, in connection with the *daily motion*
of the Earth ; hence 366 revolutions of the earth on its axis are
necessary to make 365 solar days.

ILLUSTRATION 21.

SPRING AND NEAP TIDES.

As the attraction of both Sun and Moon has a tendency to ele-
vate the waters of the ocean, when both bodies are on the same
side of the Earth, or on opposite sides, there is high or *Spring* Tide,
or if when they are at right angles there is a *Neap* Tide. To illus-
trate the Spring Tide, turn the crank till the Moon is *between* the
Earth and the Sun, or on the *opposite* side of the Earth from the
Sun.   To illustrate the Neap Tide, continue the motion of the Moon
about a quarter of a revolution around the Earth, to *quadrature*,
and her *influence* on the waters will be at *right angles* to that of
the Sun.

ILLUSTRATION 22.

THE EFFECT OF SOLAR AND LUNAR DECLINATION ON THE TIDES.

As the Moon is always near the plane of the Ecliptic, and as
the Sun declines North 23½°, and South the same number of de-
grees from the Equator, and as the tendency of the waters is to
rise highest under the bodies that cause them to rise, it will be ap-
parent by revolving the Earth and Moon, and observing their de-
clination, that *the tides* are not always highest *on the Equator*, but
sometimes *North of it*, and sometimes *South of it*.

ILLUSTRATION 23.

CAUSE OF CONSTANT AND PERIODIC WINDS, TRADE WINDS, MONSOONS, &c.

Wind is air in motion, and the trade winds are winds at and in
the vicinity of the Equator, which seem to be constantly blowing
Westward, To illustrate their apparent Westward motion, re-
volve the Earth, and observe that any point on the Equator passes

through more space than any point on the Earth in the direction of either pole. At certain distances North and South from the Equator the atmosphere keeps pace with the Earth as she revolves on her axis, but in the vicinity of the Equator it does not move so fast, hence its constant *apparent Westward motion.*

PERIODIC WINDS NORTH AND SOUTH.—The declination of the Sun North and South, which has been illustrated, has its influence in producing the periodic winds that blow North and South. By giving motion to the Instrument, the Sun becomes more or less vertical on the Northern or Southern hemisphere. As he declines North, localities North are heated by his *direct rays,* and the air ascends, and the wind *blows in* and takes its place, and as he declines South, similar results occur.

LAND AND SEA BREEZES occur daily in consequence of the daily motion of the Earth on its axis. Islands, especially within the tropics, being exposed to the more direct rays of the Sun, *heat quicker* during the day than the waters that surround them, and the air ascends and the winds blow towards them to take its place, and during the night they *cool quicker* than the waters that surround them, and the winds blow from them.

ILLUSTRATION 24.

THE MOON ALWAYS PRESENTS THE SAME SIDE TO THE EARTH.

Give motion to the Instrument, and follow the Moon with the eye while she is making one revolution around the Earth, and the same side *will continue towards* the Earth. This results from her slow axial motion. She turns once on her axis while she revolves once around the Earth.

ILLUSTRATION 25.

LENGTH OF LUNAR DAYS AND NIGHTS.

If watch is kept upon the Moon while she revolves once around the Earth, *each hemisphere* will be turned *once* to the Sun, and will be in alternate light and darkness, hence one lunar day and night is equal to about twenty-nine of our days.

ILLUSTRATION 26.

CONJUNCTION, QUADRATURE, OPPOSITION, AND PHASES OF THE MOON.

Give motion to the Instrument till the Moon comes between the Sun and Earth, and she will be in *conjunction* and at her change; advance her a quarter of a revolution around the Earth, and she will be in *quadrature* and half full; continue her motion till the Earth is between her and the Sun, and she is in *opposition* and full.

Note.—If the Earth and Moon were at their relative distances the Moon would not appear *directly outside* of the Earth, from the Sun, or *directly between* the Sun and Earth, only when at or near her nodes.

ILLUSTRATION 27.

ELLIPTICITY OF THE MOON'S ORBIT, AND ITS RELATION TO THE PLANE OF THE ECLIPTIC.

The Moon's orbit in relation to the Earth is elliptical, and it crosses the Ecliptic at two opposite points, called *nodes*. The plane of the Moon's orbit is at an angle of about 5° with the plane of the Ecliptic. To illustrate these phenomena with the Instrument, give it motion, and the Moon may be seen moving in an ellipse, alternately nearer and further from the Earth, and if the wire that carries the moon is properly adjusted, she will slightly alternate North and South of the plane of the Ecliptic every revolution she makes around the Earth.

ILLUSTRATION 28.

RETROGRESSION OF THE MOON'S NODES

The Moon's *nodes move Westward* a degree and a fraction during each Lunation. Their Westward movement will be better understood by examining the form and motion of the disk that is attached to the largest wheel, at the outer end of the arm that carries the Earth and Moon. The disk is slightly inclined on the face, which causes (when motion is given to the Instrument) the Moon to move in an elliptical orbit, and also to cross the plane of

the Ecliptic North and South. And as the wheel that carries the disk revolves slowly West, making but one revolution while the Earth revolves eighteen times and a fraction around the Sun, (equal eighteen years and a fraction), the inclination of the disk is always changing its position slowly in relation to the plane of the Ecliptic, which causes the Moon to cross the plane of the Ecliptic a degree and a fraction further West every Lunation.

ILLUSTRATION 29.

SYNODICAL AND SIDERIAL REVOLUTIONS OF THE MOON.

To make this illustration plain, bring the Earth to the Winter Solstice, and the Moon *under* the Earth, between the Earth and Sun. Revolve the Instrument till the Moon comes again directly *under* the Earth, and she will have made a *siderial revolution*. If the motion of the Earth and Moon is continued till the Moon comes *between* the Earth and Sun again, she will have made a *synodical revolution*. She makes the Siderial revolution in about $27\frac{1}{3}$ days, and the Synodical in about $29\frac{1}{2}$ days. If the Earth had no annual motion, and the Moon to revolve, she would make her synodical and siderial revolutions in the same period.

ILLUSTRATION 30.

SOLAR AND LUNAR ECLIPSES.

When the Moon passes *between* us and the Sun, she hides his light from us, hence a solar eclipse; and when the Earth comes *between* the Moon and Sun, her light is obscured, hence a lunar eclipse. To illustrate with the Instrument, give it motion, and observe the course of the Moon, and she will at one time be between the Earth and Sun, hence a solar eclipse, and at another time she will be on the opposite side of the Earth from the Sun, hence a lunar eclipse.

ILLUSTRATION 31.

WHY SOLAR AND LUNAR ECLIPSES DO NOT OCCUR EVERY REVOLUTION OF THE MOON.

From observing the course of the Moon around the Earth, it might be inferred that there is a solar and lunar eclipse every rev-

olution of the Moon, but if we consider the Earth and Moon to assume their proper relative distances from the Sun and each other, and that the orbit of the Moon crosses the plane of the orbit of the Earth at *two points*, and that these crossing points are slowly changing their places around the Earth, it becomes apparent that the Moon will be generally so far North or so far South of the Earth that her shadow will not obscure the light of the Sun— neither the Earth's shadow obscure her light.   Eclipses can only occur when the moon and her nodes are at or near an imaginary line extending from the centre of the Sun through the centre of the Earth.

ILLUSTRATION 32.

ALTITUDE OF THE FULL MOON NORTH, AND NEW MOON SOUTH, IN WINTER.

Give motion to the Instrument till the Earth arrives at the Winter Solstice, and the Moon in conjunction.   The Sun will be seen at his *minimum altitude*, being South of the Equator $23\frac{1}{2}°$, and the Moon being always near the Ecliptic, she has a less altitude than at any other season when she is *new*.   That the Moon may attain her greatest altitude when full, give her half a revolution around the Earth to opposition, and her altitude will increase about 47°, which increase will make it greater than at any other season when she is *full*.

ILLUSTRATION 33.

ALTITUDE OF THE FULL MOON SOUTH, AND NEW MOON NORTH, IN SUMMER.

Bring the Earth to the Summer Solstice and the Moon in conjunction where she changes, and as she is always near the Ecliptic it is apparent that she has a greater altitude than at any other season when she is *new*.   That the Moon may be at her minimum altitude when full, revolve her half around the Earth to opposition, and it is apparent that her altitude is less when she is *full* than at any other season.

ILLUSTRATION 34.

THE MOON'S FIRST QUARTER LOW AND THIRD QUARTER HIGH AT THE AUTUMNAL EQUINOX.

Give motion to the Instrument till the Earth arrives at the Autumnal Equinox and the Moon in conjunction. Turn the crank slowly and the Moon will be seen moving South from the Equator *diminishing* in altitude and running *low*. During the second quarter she regains the altitude she lost during the first, and during the third she will be seen moving North from the Equator, *increasing* in altitude and running *high*.

ILLUSTRATION 35.

THE MOON'S FIRST QUARTER HIGH AND THIRD QUARTER LOW WHEN THE EARTH IS AT THE VERNAL EQUINOX.

Give motion to the Instrument till the Earth arrives at the Vernal Equinox and the Moon in conjunction. Turn the crank slowly and the Moon will be seen moving North from the Equator *increasing* in altitude and running *high*. During the second quarter she loses the altitude she gained during the first, and during the third she will be seen moving South from the Equator *diminishing* in altitude and running *low*.

ILLUSTRATION 36.

THE MOON'S LIBRATIONS.

The Librations of the Moon are of Latitude and Longitude; of Latitude when she alternately exposes a little more of her North and South Polar Regions, and of Longitude when she alternately exposes a little more of her Eastern and Western Limbs. To illustrate the' principle, imagine ourselves on the Equator of the Earth and revolve the Earth and Moon, and observe the Moon as she passes North and South of the Equator. When she passes North shee xposes more of her South Polar Regions and when she passes South she exposes more of her North Polar Regions. It is also apparent that as she revolves, a little more of the Eastern and Western Limbs of the Moon come alternately into view.

ILLUSTRATION 37.

ZENITH AND NADIR.

Wherever we may be on the Earth's surface the Zenith is an imaginary point in the heavens directly over head, and the Nadir is an imaginary point in the opposite direction. Take any point on the Earth's surface, and consider ourselves located there, a straight line passing from the centre of the Earth through *that point* will point to the Zenith, and if it is extended in the *opposite direction* it will point to the Nadir.

ILLUSTRATION 38.

THE SENSIBLE AND RATIONAL HORIZON.

If we imagine ourselves on any point of the Earth's surface and apply the *Indicator* around the Earth 90 degrees distant from us at all points it will represent the position of the plane of the Rational Horizon. The Sensible Horizon is the circle where the Earth and the sky seem to come together.

ILLUSTRATION 39.

VERTICLE CIRCLES, PRIME VERTICLE AND COLURES.

Verticle Circles are imaginary circles that pass through the Zenith and Nadir perpendicular to the horizon. Apply the Indicator around the Earth touching its surface at the point where we are on the earth, and also at the opposite point on the opposite side of the Earth and it will cut our horizon at *right angles* and represent the position of a Verticle Circle. If the Indicator is made to pass through the point we occupy, also through the East and West points of our horizon, it will represent the position of the Prime Verticle. The Colures are great Meridian Circles that pass through the Equinoctial and Solstitial points.

ILLUSTRATION 40.

CIRCLES OF PERPETUAL APPARITION AND OCCULTATION.

The Circle of Perpetual Apparition is the boundary of the space around the elevated pole where the Stars never set, and the Cir-

cle of Perpetual Occultation is the boundary of that space around the depressed pole where the Stars never rise. Were we on the Equator our horizon would pass through the poles and each half of the heavens would rise and set alternately as the Earth rotates on her axis. Were we to go North 40 degrees the North Pole would be apparently elevated 40 degrees, and the South Pole apparently depressed the same number of degrees, and the space in the heavens around the North Pole would have a radius of 40 degrees, in which the Stars would never set, and the space in the heavens around the South Pole would have an equal radius in which the Stars would never rise. To illustrate the principle let us imagine ourselves on the parallel 40 degrees North, keeping constant watch, as the Earth is made to revolve, on some object towards which the North Pole is directed, and it will be apparent that the object will be constantly in view, and it will also be equally apparent that the interposition of the Earth *will prevent us seeing* other objects South of the South Pole.

ILLUSTRATION 41.

THE SUN'S ZENITH DISTANCE, ALTITUDE AND DECLINATION FOR LATITUDE 40 DEGREES NORTH OR SOUTH, WHEN THE EARTH IS AT THE VERNAL OR AUTUMNAL EQUINOX.

The Sun's Zenith Distance is his distance from the Zenith measured on a Verticle Circle. His Altitude is his distance from the horizon measured on a Verticle Circle, and his Declination is his distance North or South measured from the Equinoctial. To illustrate bring the Earth to the Vernal Equinox and the Sun will be on the Equator. Now if we imagine ourselves 40 degrees North or South of the Equator, at mid-day, and apply the Indicator around the Earth distant from us at all points 90 degrees, it will represent our horizon, and it will be apparent that the Sun has no declination as he is on the Equator, that his Zenith distance is 40 degrees, equal to our Latitude; and his altitude is 50 degrees, the compliment of his Zenith distance.

ILLUSTRATION 42.

THE SUN'S ZENITH DISTANCE, ALTITUDE AND DECLINATION FOR LATITUDE 40 DEGREES NORTH WHEN THE EARTH IS AT THE SUMMER SOLSTICE.

To illustrate bring the Earth to the Summer Solstice and the Sun will be on the Northern Tropic. Now if we imagine ourselves 40 degrees North of the Equator at mid-day and apply the Indicator around the Earth distant from us at all points 90 degrees, it will represent the horizon and the Sun's Declination will be $23\frac{1}{2}$ degrees North, his Zenith distance is $16\frac{1}{2}$ degrees, and his Altitude is $73\frac{1}{2}$ degrees, the compliment of his Zenith distance.

ILLUSTRATION 43.

THE SUN'S ZENITH DISTANCE, ALTITUDE AND DECLINATION FOR LATITUDE 40 DEGREES NORTH WHEN THE EARTH IS AT THE WINTER SOLSTICE.

Bring the Earth to the Winter Solstice and the Sun will be on the Southern Tropic. Now, if we imagine ourselves 40 degrees North of the Equator at mid-day, and apply the Indicator around the Earth distant from us at all points 90 degrees, it will represent our horizon, and the Sun's Declination is $23\frac{1}{2}$ degrees South, his Altitude is $26\frac{1}{2}$ degrees, and his Zenith distance is $63\frac{1}{2}$ degrees, the compliment of his Altitude.

ILLUSTRATION 44.

A RIGHT, OBLIQUE, AND PARALLEL SPHERE.

' In a Right Sphere the apparent daily revolutions of the heavenly bodies are in circles perpendicular to the horizon. In order that they may appear so, we must be at the Equator. Let us imagine ourselves on the Equator, and apply the Indicator around the Earth 90° distant from us at all points, and it will pass through the poles and represent our horizon. Now, revolve the Earth, and consider the Equator and parallels extended into the heavens, and they will be perpendicular to our horizon, and properly represent the course of the daily circles of a Right Sphere.

AN OBLIQUE SPHERE.—The circles of daily motion in an Oblique Sphere are *Oblique* to the horizon. To illustrate, let us con-

sider ourselves 40° North of the Equator, and apply the Indicator around the Earth 90° distant from us at all points, and it will represent our horizon. Now, it may be seen by observing the parallels, and considering that they truly represent the course of the circles of daily motion, that they are *Oblique* to our horizon.

A PARALLEL SPHERE.—The circles of daily motion of a Parallel Sphere are *parallel* to the horizon. Let us imagine ourselves on either pole, and apply the Indicator around the Earth on the Equator, and it will represent the horizon. Now, as all the parallels are *parallel* to the Equator, it is apparent that as they represent the course of the daily circles, they are parallel to the horizon, which coincides with the Equator.

ILLUSTRATION 45.

THE AZIMUTH AND AMPLITUDE OF A HEAVENLY BODY, ON, OR ABOVE THE HORIZON.

Azimuth is reckoned 90° on the horizon from the North or South *point*, and Amplitude is reckoned 90° on the horizon from the East or West *point*. To illustrate, let us imagine ourselves 40° North of the Equator, and apply the Indicator around the Earth 90° distant at all points, to represent our horizon. If the body is on the horizon West of North, count the number of degrees from the Meridian that it is West, for its Azimuth. For its Amplitude, count the number of degrees that it is East of the West *point*. When the body is above the horizon, consider a verticle circle to pass through it, and reckon the *Azimuth* from the Meridian to where this circle cuts the horizon, and the *Amplitude*, from the West *point* to where this circle cuts the horizon.

☞ As *many more illustrations* can be made with this Apparatus that are not contained in this GUIDE, the *Teacher* of Geography and Astronomy, *to make his work thorough,* should have the Lunatellus or Heliotellus always present during each recitation, that *every idea* contained in the lesson, or suggested by it, may be illustrated, if possible, to the eye.

☞ We do not deem it necessary to give reference to sections or paragraphs in the various Geographies and Astronomies now in use that contain the matter of the illustrations in this GUIDE, as they may be readily suggested by the Teacher, as the classes advance.
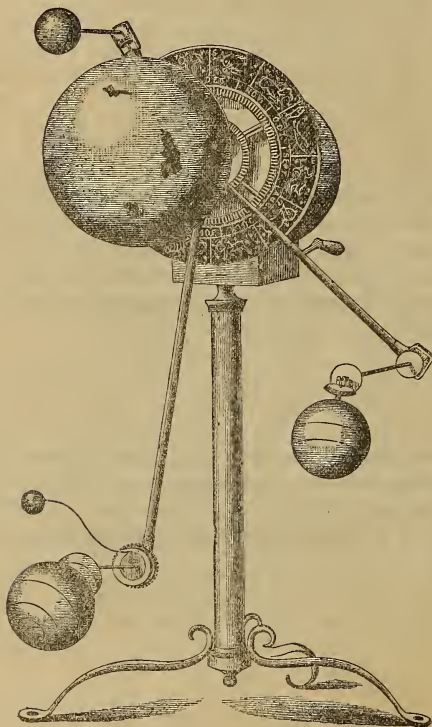
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Fig. 2.—Heliotellus.

HELIOTELLUS.

(SEE CUT ON OPPOSITE PAGE.)

The Heliotellus, in **material, construction** and **operation**, is similar to the Lunatellus, and embraces the Sun, Earth and Moon, and the **two inferior planets**. It illustrates all that the Lunatellus does, and in addition the **phenomena** of Mercury and Venus.

———— • ————

MERCURY.

ILLUSTRATION 1.

YEARLY AND DAILY REVOLUTIONS OF MERCURY.

In nature Mercury revolves once around the Sun in about 87 days, and rotates once on his axis, in about 24 hours. In the Instrument, when in motion, he revolves around the sun with a velocity *relative* to the annual velocities of the Earth, and Venus, and also rotates on his axis with a velocity *relative* to the velocities which they have on their axes.

ILLUSTRATION 2.

MERCURY'S AXIS PERPENDICULAR TO THE PLANE OF HIS ORBIT—ALSO ITS PARALLELISM.

Apply the Indicator around Mercury on his Equator, and it will represent the position of the planes of his Equator and Orbit as they coincide. Now, since these planes coincide, it is apparent that his axis is perpendicular to both, and by keeping watch on Mercury as he revolves around the Sun, his axis will be seen always parallel to itself.

ILLUSTRATION 3.

MERCURY'S DAYS AND NIGHTS EQUAL.

It is apparent that the poles of Mercury at every point in his orbit are equi-distant from the Sun, and that his rays at all times

reach them. This being the case, it follows that 180° of his Equator is constantly in the light of the Sun, and as he in nature rotates uniformly on his axis, his days and nights are always equal.

ILLUSTRATION 4.

NO CHANGE OF SEASONS ON MERCURY.

As a rule, the nearer overhead the Sun is, or the more direct his rays are, the more intense is his heat. As the planes of Mercury's Equator and Orbit coincide, his axis being perpendicular to both, the Sun's rays are constantly direct on his Equator, and grow more and more oblique towards his poles; consequently the temperature diminishes from his Equator to his poles, and is constantly uniform on each parallel.

ILLUSTRATION 5.

INFERIOR AND SUPERIOR CONJUNCTIONS OF MERCURY.

Give the Instrument motion till Mercury comes between the Earth and Sun, and he will be in *inferior* conjunction. Continue the motion of the Instrument till Mercury arrives on the opposite side of the Sun from the Earth, and he will be in *superior* conjunction.

ILLUSTRATION 6.

MERCURY'S STATIONARY POINTS.

To illustrate, give motion to the Instrument till the arms that carry Mercury and the Earth are at right angles. If we observe Mercury when he and the Earth are made to revolve, he for a short time will not appear to move in his orbit, because his pathway at that point deviates but little from a straight line which would pass from the Earth through him into space.

ILLUSTRATION 7.

WHY MERCURY IS NOT VISIBLE AT INFERIOR AND SUPERIOR CONJUNCTIONS.

Bring Mercury to Inferior Conjunction and he cannot be seen as his dark side is towards the Earth. Neither can he be seen

when revolved to Superior Conjunction in consequence of the intensity of the Sun's light that intervenes between him and the Earth. When he happens at his stationary points during the months of March and April, August and September, he may be seen in the twilight before Sunrise and after Sunset.

ILLUSTRATION 8.

PHASES OF MERCURY.

Bring Mercury to Inferior Conjunction and he is invisible, as his dark side is towards the Earth. Continue the motion of the Instrument till Mercury is in *quadrature*, and like the Moon when she is in quadrature, half of his enlightened side will be towards the Earth. Next, bring Mercury to Superior Conjunction and as he is on the opposite side of the Sun from the Earth the whole of the enlightened side will be towards the Earth; as he continues in his orbit he presents less and less of his enlightened surface till he comes again to Inferior Conjunction.

VENUS.

ILLUSTRATION 1.

YEARLY AND DAILY REVOLUTIONS OF VENUS.

In nature Venus revolves once around the Sun in about 225 days, and rotates once on her axis in a little less than 24 hours. In the Instrument, when put in motion, she revolves around the Sun with a velocity *relative* to the annual revolutions of Mercury and the Earth; and she also rotates on her axis with a velocity *relative* to the velocities which they have on their axes.

ILLUSTRATION 2.

INCLINATION OF THE AXIS OF VENUS—ITS PARALLELISM AND THE PLANE OF HER ORBIT.

Venus is pivoted by her North Pole to the gearing. The axis

of Venus is inclined 75 degrees to the plane of her orbit, causing her Tropics to be only 15 degrees from her Poles and her Polar Circles only 15 degrees from her Equator. Apply the Indicator around Venus, touching her Northern Tropic at the *highest point* and her Southern Tropic at the *lowest point* to represent the plane of her orbit, and her axis will be at its proper inclination to it. Now as her axis has always the same inclination it is constantly parallel to itself.

ILLUSTRATION 3.

DECLINATION OF THE SUN ON VENUS.

To illustrate the Sun's declination on Venus give motion to the Instrument till she arrives at the Summer Solstice, and he will be verticle to Venus 75 degrees North of her Equator, and if her motion around the Sun is continued till she arrives at the Winter Solstice he will be verticle to Venus 75 degrees South of her Equator. Now as Declination on Venus is measured from the Equinoctial of Venus North and South; the maximum declination of the Sun on Venus is equal to the number of degrees that her axis is inclined to the plane of her orbit.

ILLUSTRATION 4.

EIGHT SEASONS ON VENUS AT HER EQUATOR AND FOUR AT HER POLES.

To illustrate the seasons of Venus, give motion to the Instrument till she arrives at the Vernal Equinox, and the Sun will be on her Equator, hence midsummer there. Advance her in her orbit till she arrives at the Summer Solstice, hence midsummer at the Northern Tropic. Advance her next till she arrives at the Autumnal Equinox, and the Sun will be again on her Equator, hence midsummer again at her Equator. Next bring her to the Winter Solstice, hence midsummer at her Southern Tropic. It is now plain that as the Polar Regions of Venus are not far North nor South of her Tropics, that they correspond to our Temperate Zones, hence four seasons in each during one of her years. And

since the Sun crosses her Equator twice in one of her years, and declines 75 degrees North and 75 degrees South, she has two Summers at her Equator, and if she has two Summers there, she must have two Springs, and two Autumns, and two Winters.

ILLUSTRATION 5.

VENUS THE MORNING AND EVENING STAR.

To make this illustration plain revolve the Instrument till Venus is *above* the Sun and the Earth at the Vernal Equinox, and the direction of the motion of the Earth on its axis shows that the Sun sets in the evening before Venus. To show her as the Morning Star continue the motion of the Instrument till Venus is *above* the Sun and the Earth at the Autumnal Equinox, and the direction of the motion of the Earth on its axis shows that Venus rises before the Sun.

ILLUSTRATION 6.

SYNODIC PERIOD OF VENUS.

It requires Venus about 225 days to revolve once around the Sun, which is her *Siderial period*. Her *Synodic period* is represented by revolving Venus from Inferior Conjunction to Inferior Conjunction again. As the Earth and Venus revolve around the Sun in the same direction, the Synodic period of Venus is more than double the length of the Siderial period. It contains about 585 days, half of which time Venus is the Morning Star and the other half the Evening Star.

ILLUSTRATION 7.

PHASES OF VENUS.

Bring Venus to Inferior Conjunction and she is invisible, as the Earth is on the dark side of her. Revolve her till she is in *quadrature*, and the half of the side that was turned from the Earth at conjunction is now turned towards the Earth. Next revolve Ve-

nus to Superior Conjunction and her disk will be circular, as the whole half that is enlightened is turned towards the Earth.

ILLUSTRATION 8.

TRANSITS OF MERCURY AND VENUS.

Sometimes Mercury and Venus pass *directly* between the Earth and the Sun. When this happens each seems like a small black spot crossing his disk. To illustrate with the Istrument give it motion and observe Mercury and Venus pass between the Earth and the Sun.

If Mercury, Venus and the Earth were at their relative distances from the Sun they would seldom pass over his disk.

ILLUSTRATION 9.

OCCULTATION OF VENUS.

The Occultation of a heavenly body takes place when another heavenly body passes between it and the Earth and conceals it from view. The Moon, at times, passes between the Earth and Venus and hides her from view. By giving motion to the Instrument you can readily perceive, from the arrangement and motions of the Earth, Moon and inferior Planets, how an Occultation of Venus may occur.

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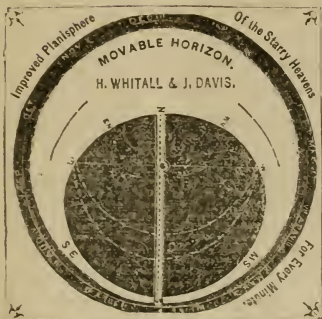
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The movable horizon, which answers to the natural one, turns on the point that designates the North Pole as its centre of motion, and its circumference is divided into *fourteen hundred and forty* equal parts, corresponding to the number of minutes in each day.

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TESTIMONIALS.

From B. PIERCE, L. L. D., Prof. of Astronomy and Mathematics, Harvard University, *Cambridge, Mass.*

       I have examined Prof. H. Whitall's Planisphere, and it seems to me to be a simple and economical substitute for a Celestial Globe, and capable of being used for all the ordinary purposes to which globes are applied, and is especially to be recommended for the simplicity with which it presents to the eye some of the popular problems of Astronomy, and for the readiness with which it will enable one to ascertain the names and positions of the Stars.

We fully concur in the recommendation of Prof. Pierce.

Hon. Gideon Wells, Secretary of the Navy.
C. H. Davis, Rear Admiral and Chief of Bureau of Navigation.
A. D. Bache, Supt. of U. S. Coast Survey.
Joseph Henry, Secy. Smithsonian Institute.
J. G. Barnard, Brig. Genl. and Lt. Col. of Engineers.
J. Saxon, Asst. Supt Weights and Measures.
L. M. Goldsborough, Rear Admiral U. S. Navy.

J. E. Hillgard, U. S. Coast Survey Office.

Father Jas. Curley, Prof. Astronomy and Mathematics George-
town College, D. C.

E. B. Metcalf, Principal of Wayland School, Worcester, Mass.

John D. Philbrick, Supt. Public Schools, Boston.

Daniel Leaca, Supt. Public Schools, Providence.

Alpheus Crosby, A. M., Principal State Normal School, Salem,
Mass.

Henry Riddle, Asst. Supt. Common Schools N. Y. City.

Rev. H. Mattison, Author of High School Astronomy, &c.

S. S. Randall, City Supt. Public Schools, N. Y. City.

William Smaton, Principal Grammar School, No. 19, N. Y. City.

J. F. Stoddard, Principal of Grammar School, No. 10, N. Y. City.

Thomas Foulke, Principal Friends' Seminary, N. Y. City.

Thomas Hunter, Principal, No. 35, Fifteenth Ward, N. Y. City.

Thomas F. Harrison, Principal, No. 41, Ninth Ward, N. Y. City.

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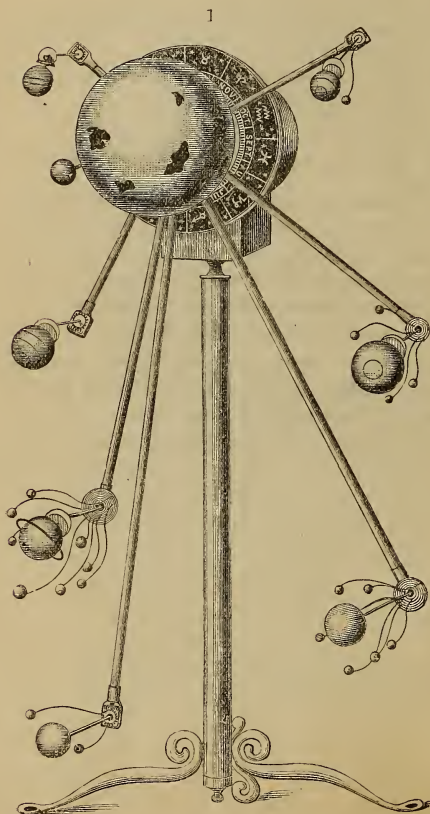
C. Van Norman, No. 5 West Thirty-Fifth St., N. Y. City.

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Fig. 1.—Planetelles.

PLANETELLES.

(SEE CUT ON OPPOSITE PAGE.)

Success, after the lapse of nearly thirty years, has finally crowned the efforts of the inventor of the Lunatellus and Heliotellus, in contriving the PLANETELLES, the *first Mechanical device ever made* that represents the motion of the Sun on his axis, the *relative* yearly and daily motions of the *eight primary Planets,* and the various motions of the *twenty-one Satellites* around the Sun, around their Primaries and on their axes in different periods. *Eighty* (80) *motions* of these bodies, faithfully representing the grand Mechanism of the Solar System, with the Phenomena resulting therefrom, are clearly exhibited to the eye, by this invaluable Instrumetn—this Mechanical Wonder.

The *Model* of this improvement has been deposited, piecemeal, in the United States Patent Office, at Washington City, and another Instrument of large *dimensions,* of the same kind, is now being constructed for Public use.